The Iowa River Bridge on Relocated U.S. 20 A Launched Steel I-Girder Structure

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ABSTRACT

This paper discusses the environmental issues and restrictions surrounding the proposed site of the Iowa River Bridge crossing and then focuses on the difficult site accessibility issues, the proposed sequencing of the substructure construction and the launched construction techniques proposed for the erection of the superstructure units.

PROJECT DESCRIPTION

For years the portion of Highway U.S.20 through Hardin and Grundy counties of middle Iowa has consisted of two lane county blacktop roads weaving through many small communities. The primary reason for the discontinuous alignment has been the environmentally sensitive Iowa Greenbelt in the heart of Iowa. The Greenbelt, which runs along the banks of a 50-mile stretch of the Iowa River, is home to many endangered species of plants, animals and aquatic life:

- Bald eagles occupy several winter roosting areas that provide the needed protection from winter storms.
- Several rare species of mussels, some found only in the river waters of the Iowa Greenbelt area, are very sensitive to purity and temperature changes to water quality.
- Natural crop sites of the Monkshood plant, a federally protected poisonous herb, exist in the river valley in addition to the many plant species common to the wetlands of the riverbanks.

In addition to the many environmental concerns, poor sub-soils, slope instabilities and difficult site accessibility issues add to the complexities of constructing a bridge in the area.

To complete the new U.S. 20 alignment, a relocated portion of this four lane highway would need to cross through the Greenbelt and bridge the 460 m Iowa River valley thus permanently affecting one or more of the environmentally sensitive areas of this ecosystem. Corridor studies began in the early 70's however with the evolution of new environmental regulations came new reasons to delay the project. Finally in 1996, the site was finalized and six alternative structure types and erection methods were evaluated.

The Iowa Department of Transportation preferred a low profile structure to minimize the visual impact of this scenic area. Thus the selected alternative consists of a weathering steel I-Girder superstructure erected as two parallel 12.0 m wide deck structures each consisting of five equal spans of 92 m. Each deck structure will consist of a 230 mm concrete slab with a 38 mm low-slump concrete wearing course supported by a system of four 3450 mm deep I-girders spaced at 3600 mm centers. The deck structures will be supported on cast-in-place

Artist's rendering of Proposed Iowa River Bridge

reinforced concrete substructure units consisting of two column bents ranging in height from 20 m to 38 m and founded on drilled shafts or driven H-piles.

To minimize the impacts to the environment and to facilitate construction of the bridge, a launched erection method is proposed for the deck structures. This erection method will allow the steel portions of the superstructure to be constructed behind one of the bridge abutments and pushed (or pulled), with deck forms and reinforcing in place, from pier to pier across the river valley.

CONSTRUCTION DIFFICULTIES

The selected site for the new, river crossing posed many construction challenges for the designers:

- Due to the environmental concerns, numerous construction mitigation restrictions were established and subsequently became more restrictive as the final design of the project progressed. These restrictions included:

  - Prohibited construction activities on the west slopes (near the eagle's roost) during a "Winter shut-down" period between November 1st through April 15t

  - Monitored construction activities on the east slopes during the period between November 1st and April 15th with the possibility of a shut down at any time if it is determined that the noise and/or activities disrupt the roosting habits of the eagles.

  - Prohibited use of causeways and/or temporary bridges to cross the river.

  - Protection of all equipment used in the river valley by a containment system designed to prevent fluid spills (fuel, oil etc.) from reaching the river.

  - Limited construction activities which must work around "allowable" zones of disturbance ranging from "clearing and grubbing" as required at selected construction access ways to "selective clearing (with chainsaws only) and no grubbing" in zones containing protected trees whose eventual mature heights would never exceed heights within 5 m to 10 m below the girders.

- Defined drainage paths and/or distribution systems to minimize the run-off down the side slopes from disturbed areas of the construction site, approach roadways and the eventual final bridge. Note: Paths and/or distribution systems are designed to direct rainwater (and road salts) to pre-constructed sediment basins on each side of the river.

- Removal of all excavated materials including drilling material and spoils from the drilled shaft operations to selected disposal sights above the limits of the river valley.

- Due to the remote site location in middle Iowa and a delayed bidding schedule which will place the contract letting for the bridge on the same date as the adjacent grading packages, the only initial access route to the site will be by temporary improvements to existing county roads and private drives.

- Due to the tight timeframe for the bridge construction, the restricted "winter shut down" periods and the delayed letting schedules, the bridge contractor will be required to begin construction at the two main piers on the west slopes followed by the two main piers on the east slopes working outward towards the abutments all while allowing the grading contractor to construct the approach roadways concurrent to the bridge construction.

LAUNCHED ERECTION METHOD

With the anticipation of limited construction equipment access into the river valley and with the environmental restrictions enforced, steel erection from within the valley was ruled out by the engineers and a launched erection sequence was selected as the method of construction. With stringent "winter shut-down" restrictions on the west slopes, the bridge is designed to be launched downhill along the 0.5% grade from behind the east abutment pushing with the use of hydraulic thrust pistons (or pulling with the use motors, cables and sheaves) towards the west abutment.

To facilitate the launching operations, a large launching pit excavated behind the east abutment is anticipated. Although the eventual depth of this pit will ultimately be determined by the type of roller system utilized by the contractor, the girder depth plus one meter is assumed for design. Although contractor's means and methods will also determine the eventual length of this pit, a minimum pit length of 150 m (which provided sufficient backspan erection to counterbalance the cantilevered portion of girders) is assumed for design.

To determine the relative magnitude of the launching and braking forces, 10% and 2.5% coefficients of friction are assumed respectively. A roller bearing manufacturer was contacted during the design process. Specifications for these bearings indicate a recommended design coefficient of friction of 5%. Thus by doubling the recommendation, a conservative over-turning force could be applied to the substructure units as well as provided in the design documents. Conversely, by assuming a minimum coefficient of friction equal to half of that recommended, a conservative required braking force could be provided in the design documents.

To minimize the amount of construction equipment required in the valley after launching, all deck forms, slab reinforcing, steel girders, miscellaneous bracing and the enclosed drainage system are assumed to be launched as a complete system. Initially erection runs indicated that the lead cantilever would deflect over 4500 mm when the loaded girders extended the full 92 m. However, the deflections were reduced to 3000 mm by adding a trussed launching skid and by removing the deck forms and slab reinforcing from the cantilevered portion of the launch.

To accommodate the deflection of the cantilever, a system of 275-ton hinged roller bearings at each girder centerline at each pier are assumed. The trussed launching skid is designed with the bottom chord sloping upwards a distance slightly greater than the calculated 3000 mm deflection. It is anticipated that this upward slope will allow the launching skid to land at the cantilevered end and be guided back to vertical alignment as the skid and girders are pushed (or pulled) across the span.

To provide torsional stability to the lead cantilever, a system of longitudinal X-bracing members are provided at the top and bottom flanges in the center bay of the four girder launch. The longitudinal X-bracing in conjunction with the typical lateral K-bracing and the girders form a torsionally stiff core for each of the two deck structures launched.

A three dimensional model of the entire bridge (including substructure and superstructure members) was created to check the final “in-place” girder and pier designs against the temporary design load conditions experienced during the launching operations. Numerous trial runs were attempted to develop a launching sequence that could demonstrate that temporary erection stresses would not govern the final “in-place” stresses for both the substructure and superstructure members. The model was able to accurately depict the suggested launching sequence proposed in the contract documents and as noted below:

i. After completion of pier construction, installation of permanent pot bearings, temporary erection roller bearings and excavation of the launching pit, begin erection of deck structures including the steel girders, all miscellaneous bracing, framing for the drainage system, deck forms and launching skid.

ii. Begin launching the south deck structure by pushing against a temporary reaction pier (or pulling against a permanent pier). After the cantilevered end has landed on the temporary roller bearing, been guided back to vertical alignment and temporarily set on the permanent pot bearing to focus the dead load on the pier centerline, launch the north deck structure in a similar fashion.

iii. Repeat this staggered launching sequence until the both decks have been completely launched across all five spans.

iv. Transfer loads to permanent pot-bearings and disassemble the launching nose.

Although provided as a “Suggested Erection Sequence”, the sequence shown in the plans was modeled and designed with the full anticipation that the contractor could follow the steps as noted. However, the contractor will ultimately have the flexibility to recommend alternate sequences based on preferred “means and methods”.

SUMMARY

When evaluating the proposed erection methods for a structure, many factors outside the control of the engineer may govern the direction of the design. In the case of the Iowa River Bridge, the environmental, geotechnical, site accessibility, and construction schedule concerns played a significant role in the decision to construct the bridge using a unique and challenging method of erection. By proposing the launching of the steel I-girder deck structures, the designers minimized the impacts to the environment and developed the groundwork for construction of a large bridge at a site with difficult accessibility issues. This, however, did not come without a steep price tag. The estimated construction cost of the project is now at $21,000,000. Of this estimated value, 15% to 20% of the costs can be directly attributed to design and detailing considerations that were added to accommodate the environmental concerns and site accessibility challenges.

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